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Lin et al.

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(54) **METHOD FOR MAKING SEMICONDUCTOR DEVICE AND SEMICONDUCTOR DEVICE MADE THEREBY**

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H01L 31/0216	(2014.01)
H01L 31/0224	(2006.01)
H01L 31/18	(2006.01)

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CPC ***H01L 22/20*** (2013.01); ***H01L 22/12*** (2013.01); ***H01L 31/02167*** (2013.01); ***H01L 31/022425*** (2013.01); ***H01L 31/184*** (2013.01); ***H01L 31/186*** (2013.01)

(58) **Field of Classification Search**
CPC H01L 31/184; H01L 31/186; H01L 31/22425; H01L 21/6715; H01L 22/24; H01L 22/20; H01L 22/12
USPC 438/4, 7, 8
See application file for complete search history.

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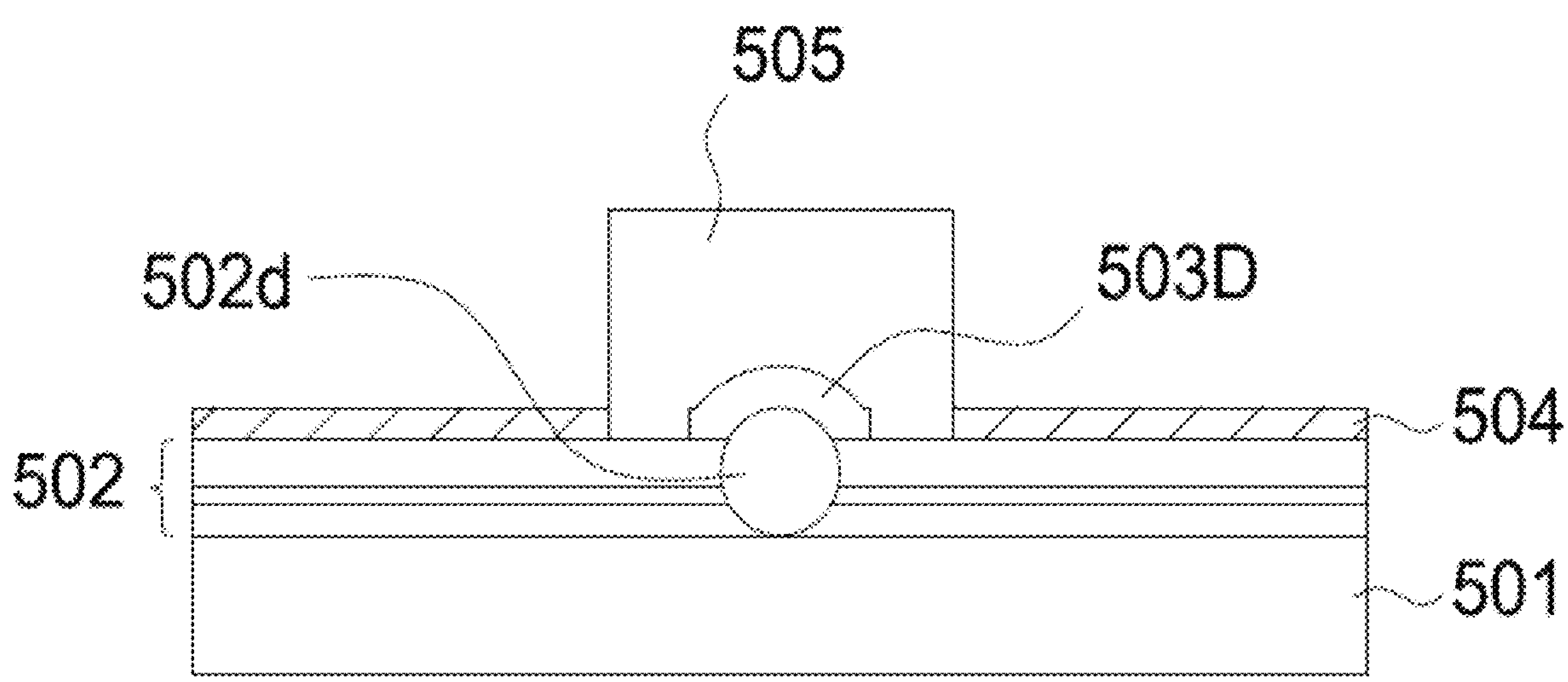
(57) **ABSTRACT**

Disclosed is a method for yield enhancement of making a semiconductor device. The method for yield enhancement of making a semiconductor device comprises the steps of: providing the semiconductor device comprising an epitaxial layer including a defect; forming a dielectric layer on the epitaxial layer; detecting and identifying a location of the defect; and etching the dielectric layer and leaving a part of the dielectric layer to cover an area substantially corresponding to the detected defect. The semiconductor device made by the method is also disclosed.

14 Claims, 15 Drawing Sheets



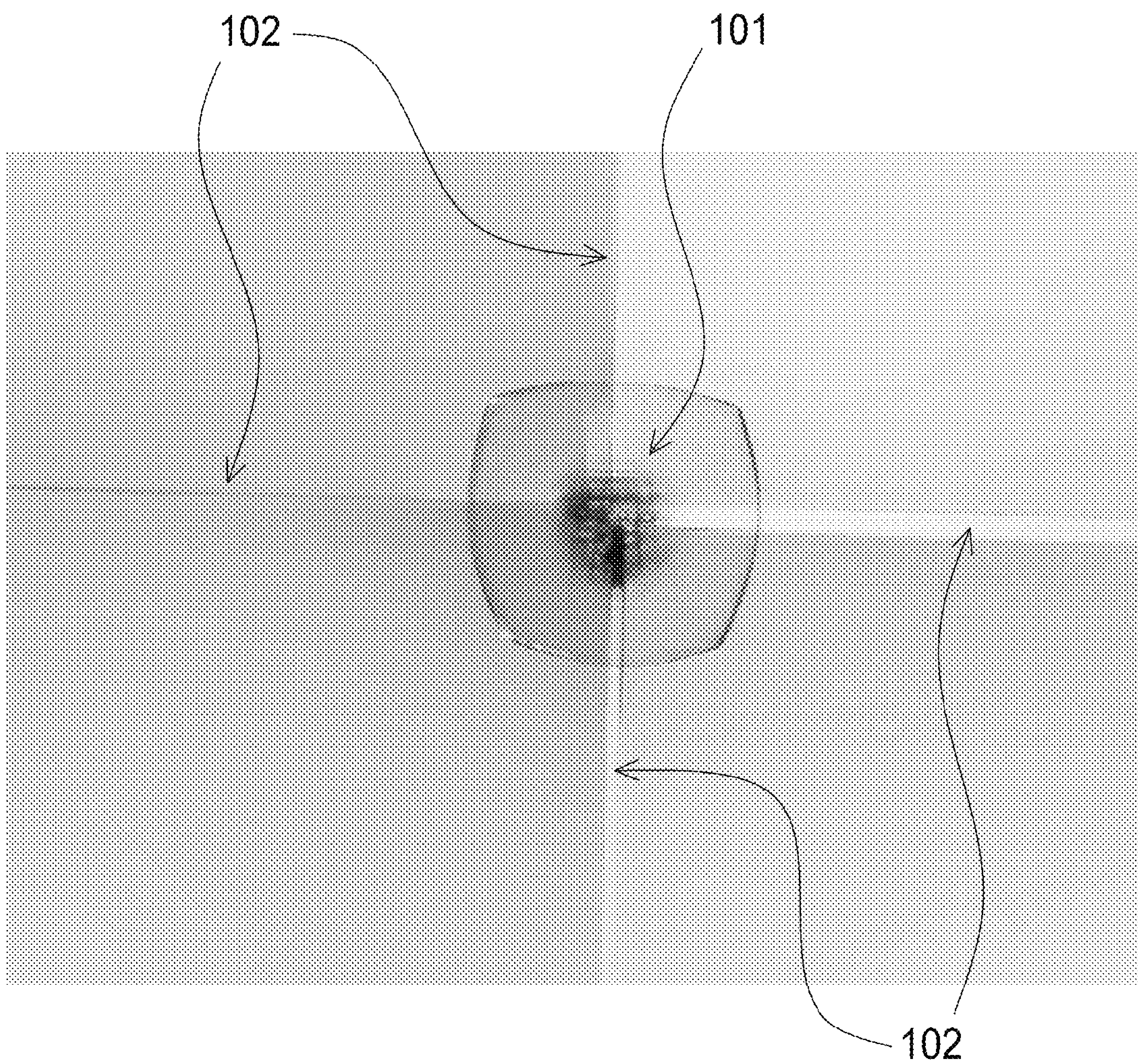


FIG.1

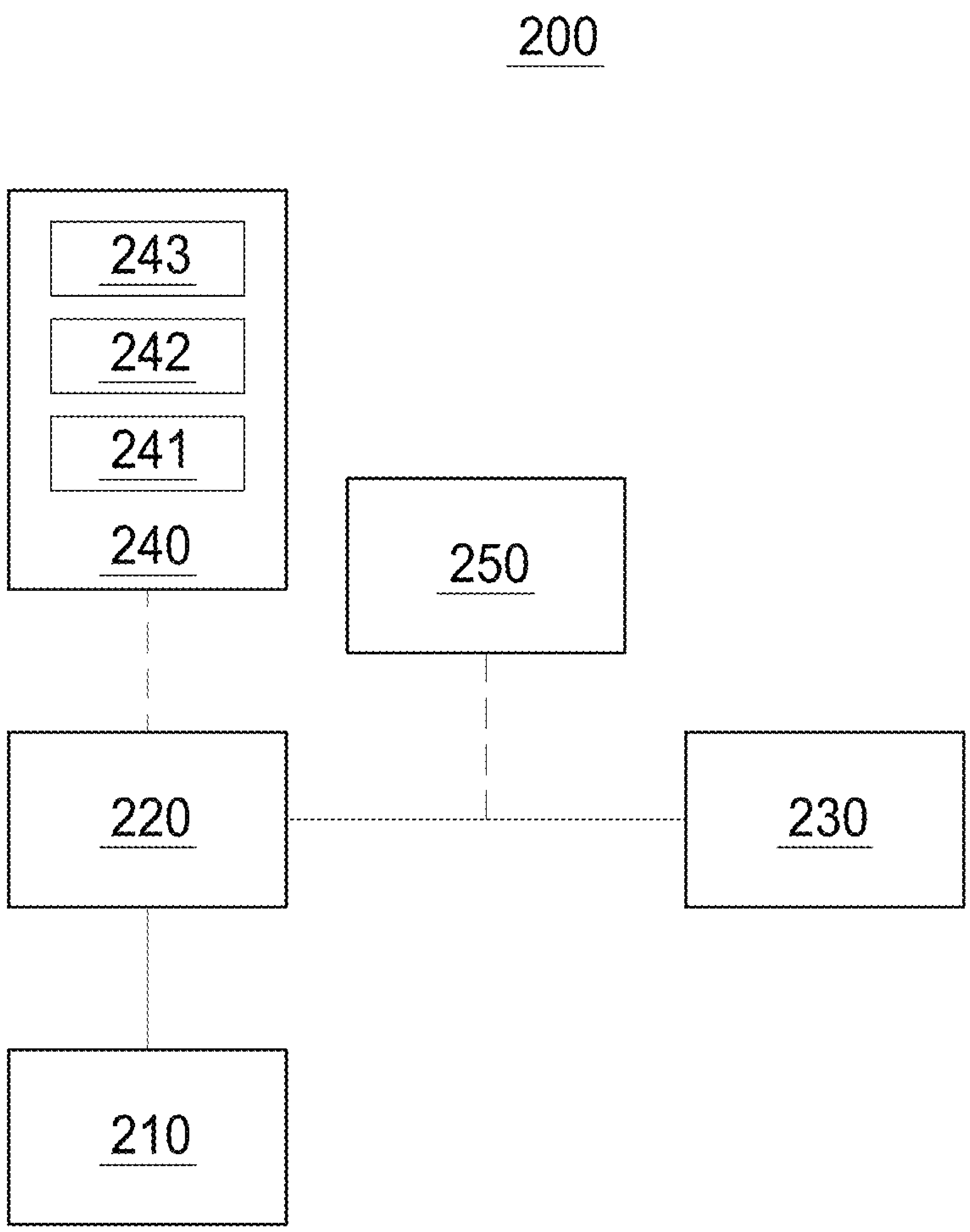


FIG.2A

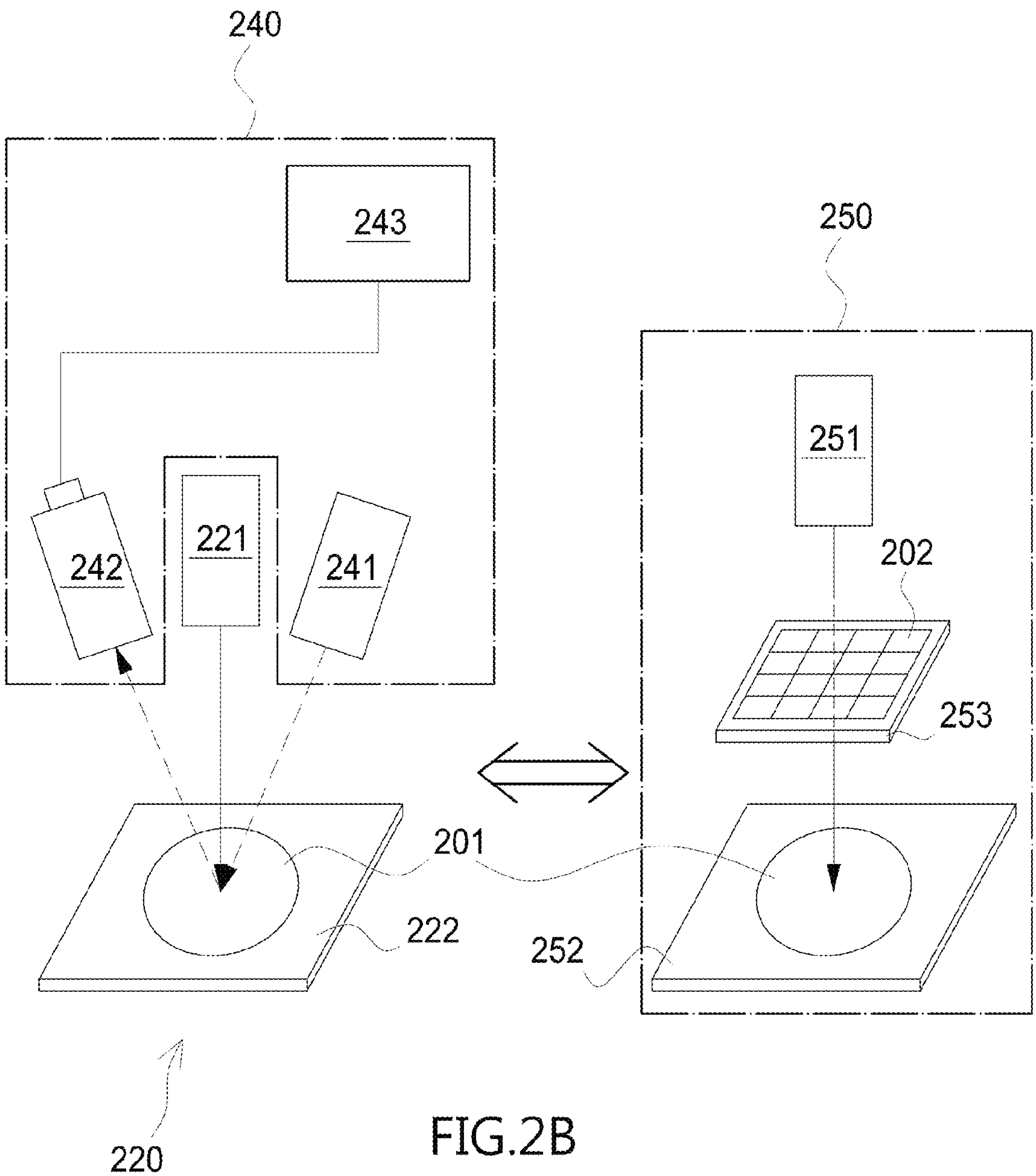


FIG.2B

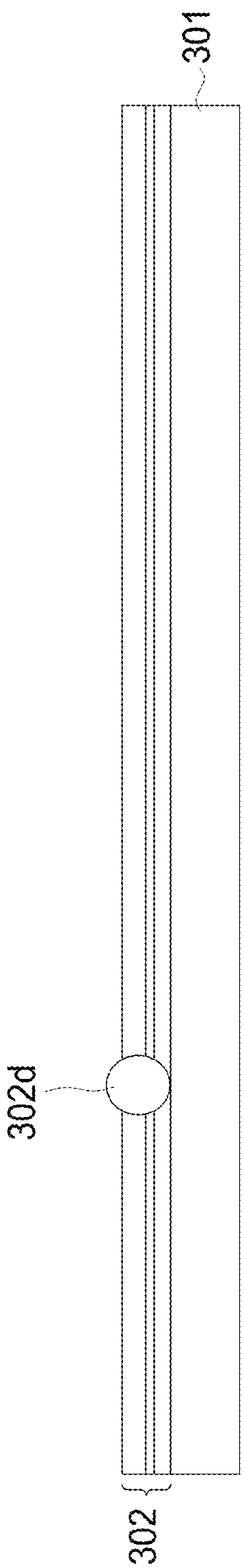

301
302d
302

FIG.3A

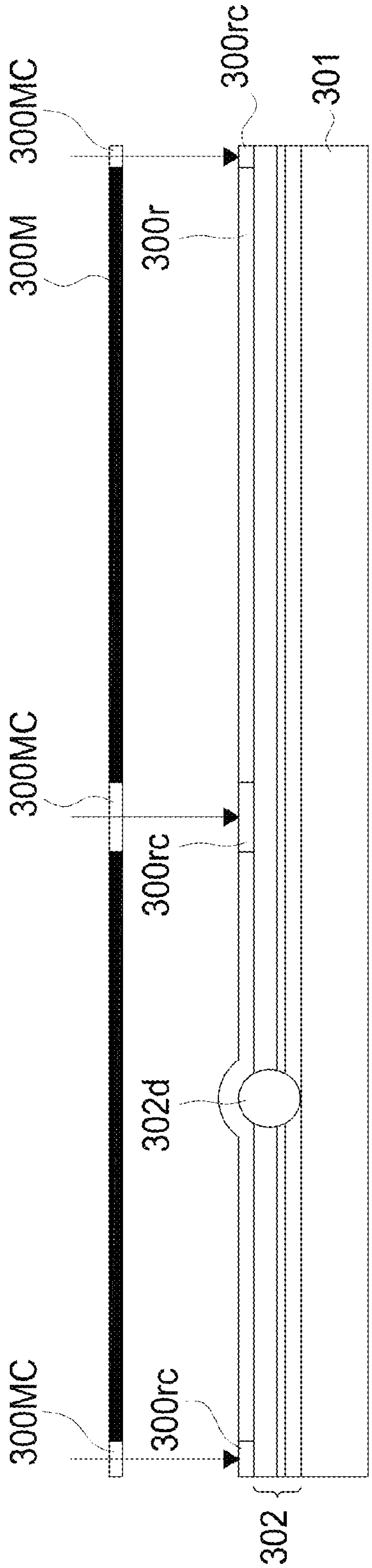
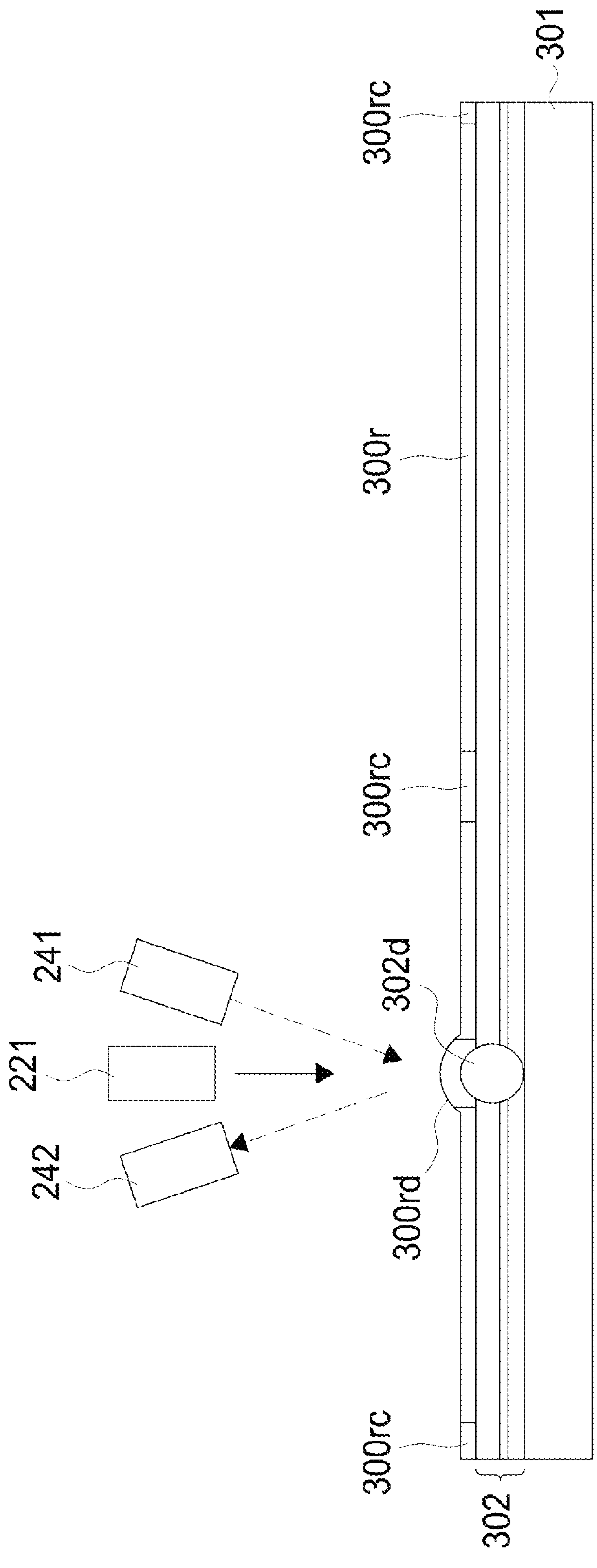
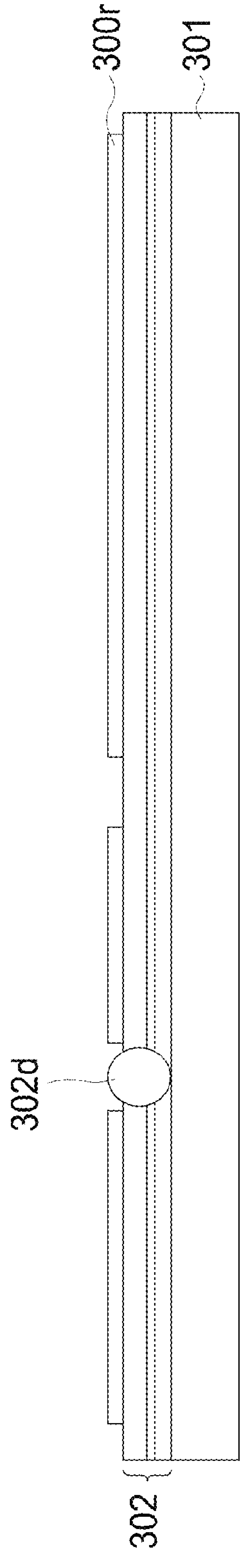

300MC
300M
300rc
300r
301
300MC
300rc
302d
300MC
300rc
302

FIG.3B



301
300rc
300r
300rc
241
221
242
302d
300rd
300rc
302

FIG.3C



300r
301
302d
302

FIG.3D

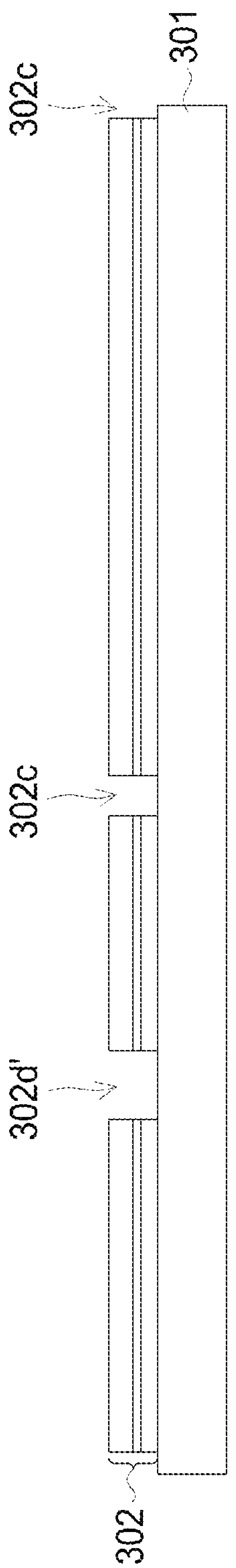


FIG.3E

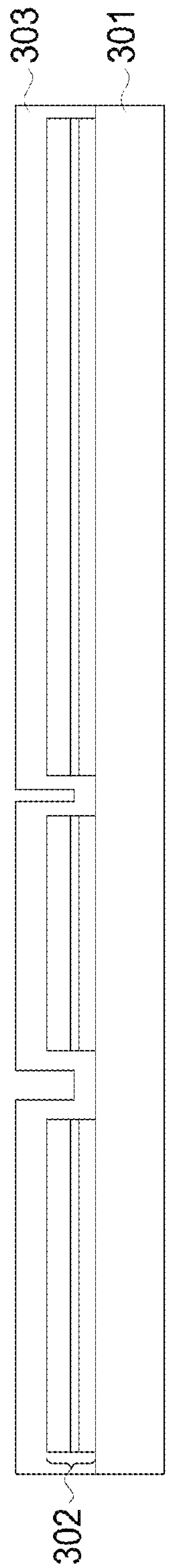


FIG.3F

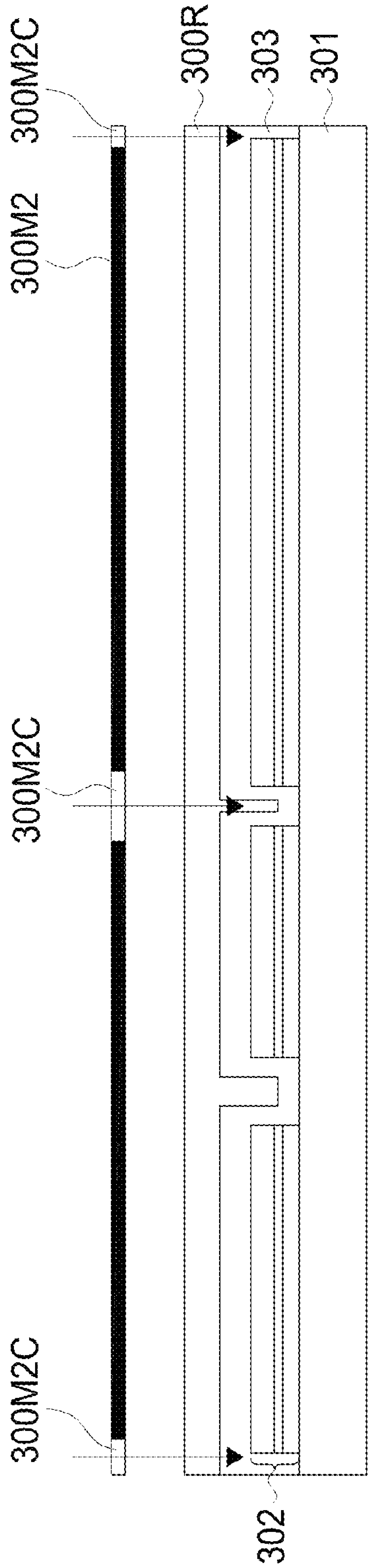


FIG.3G

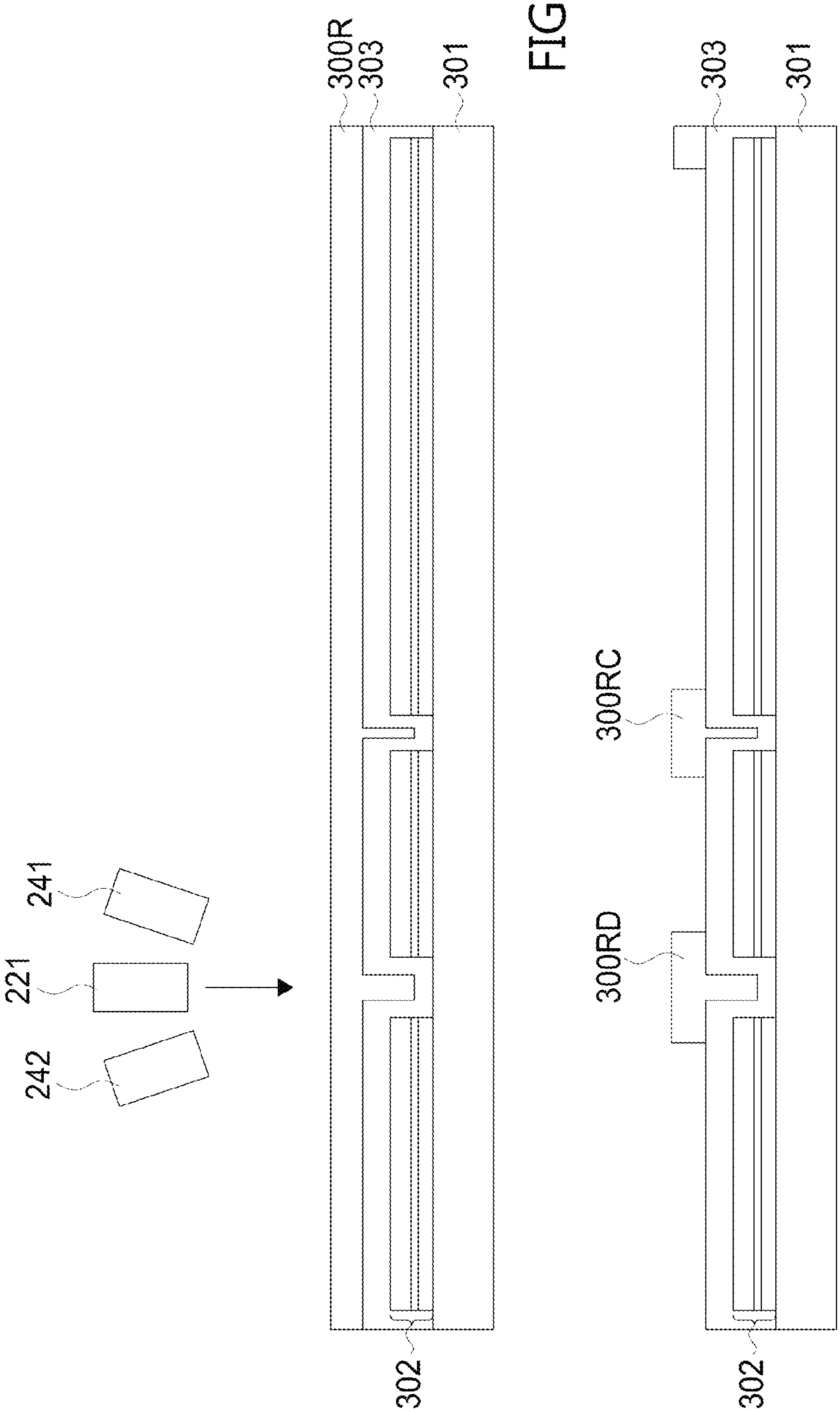


FIG.3H

FIG.3I

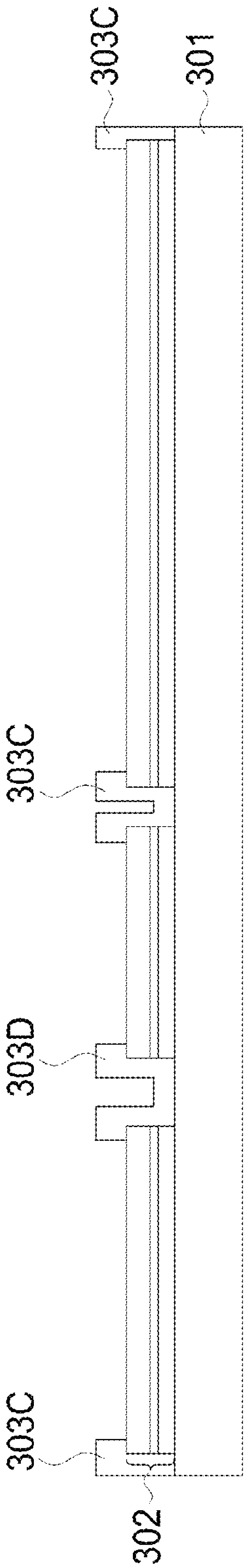


FIG.3J

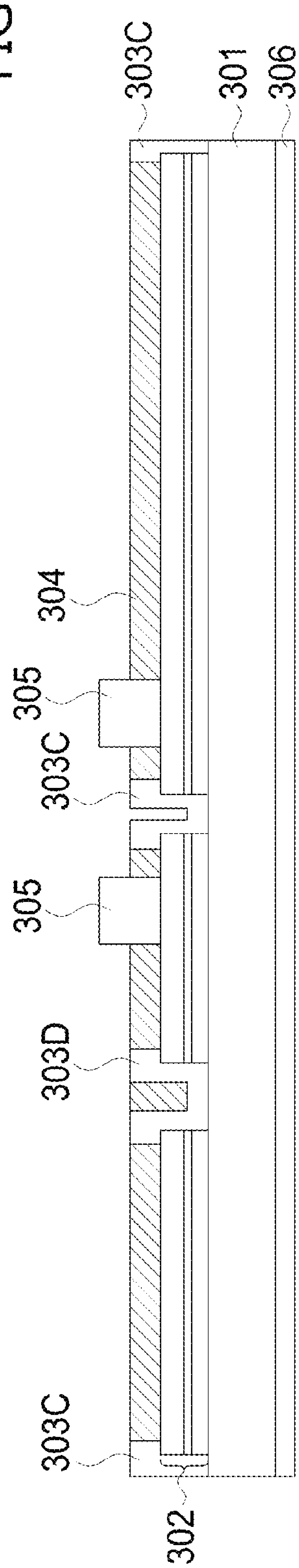


FIG.3K

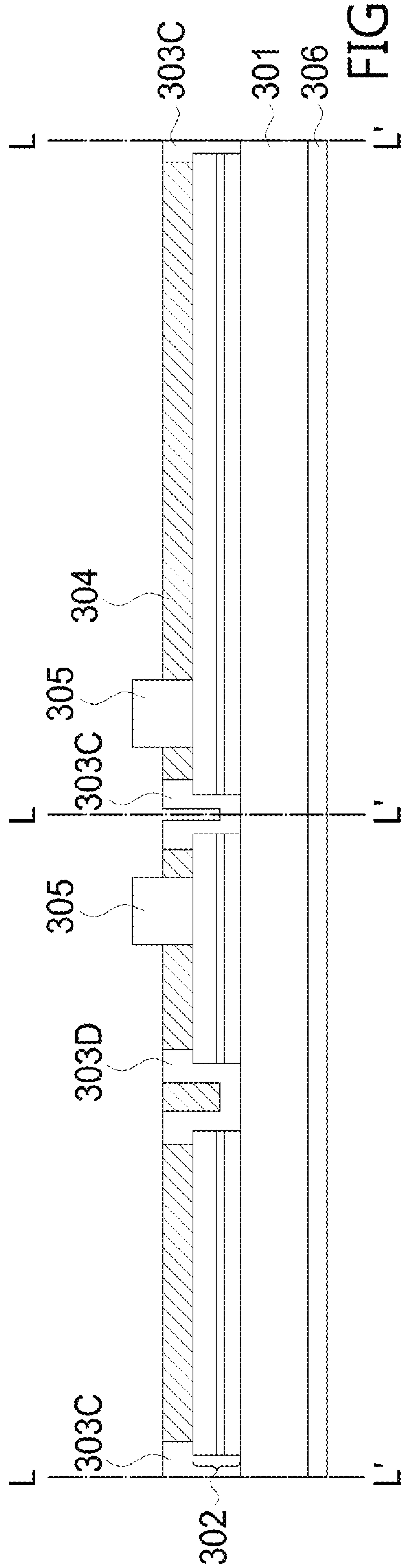


FIG.3L

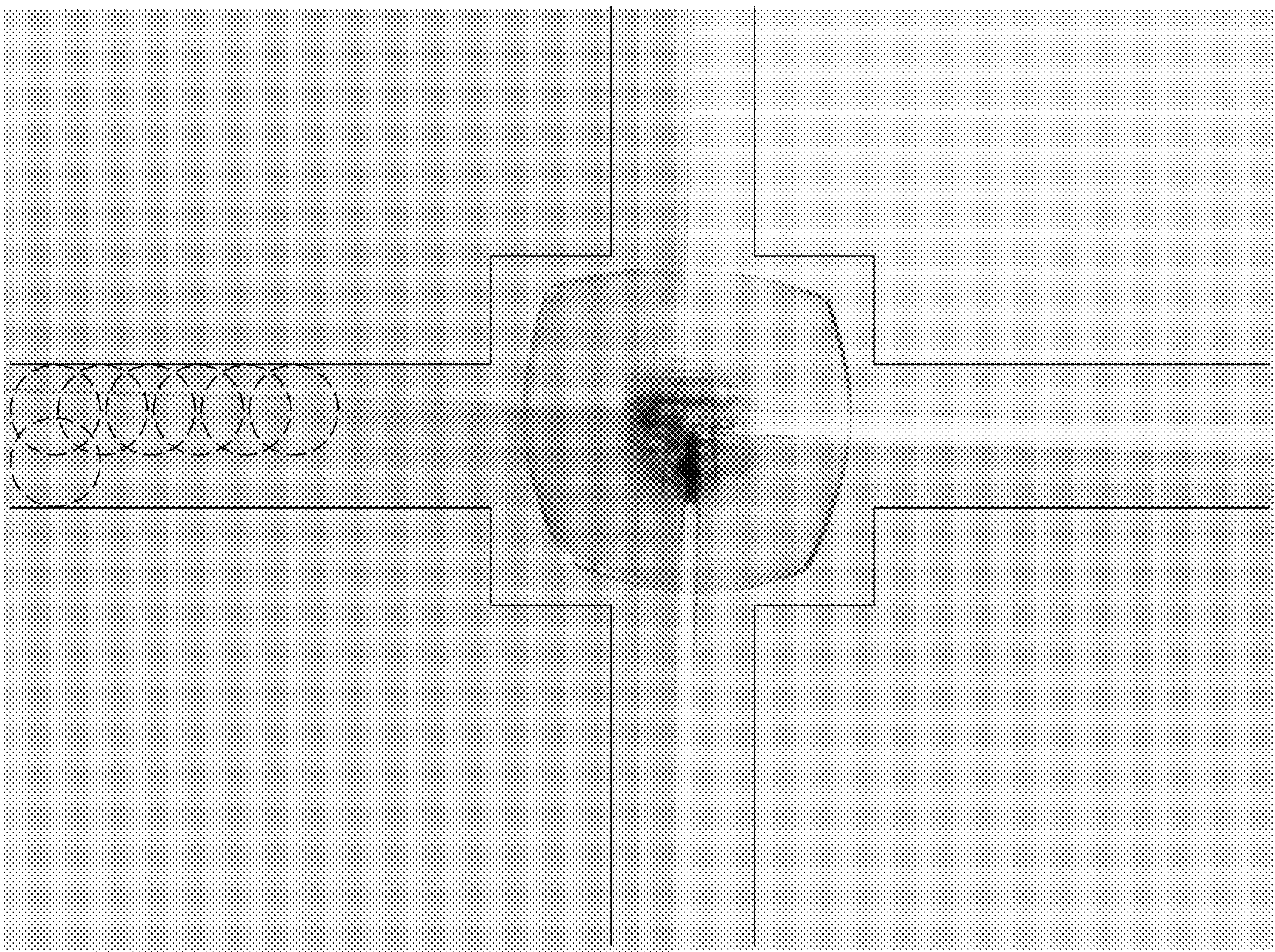


FIG.4

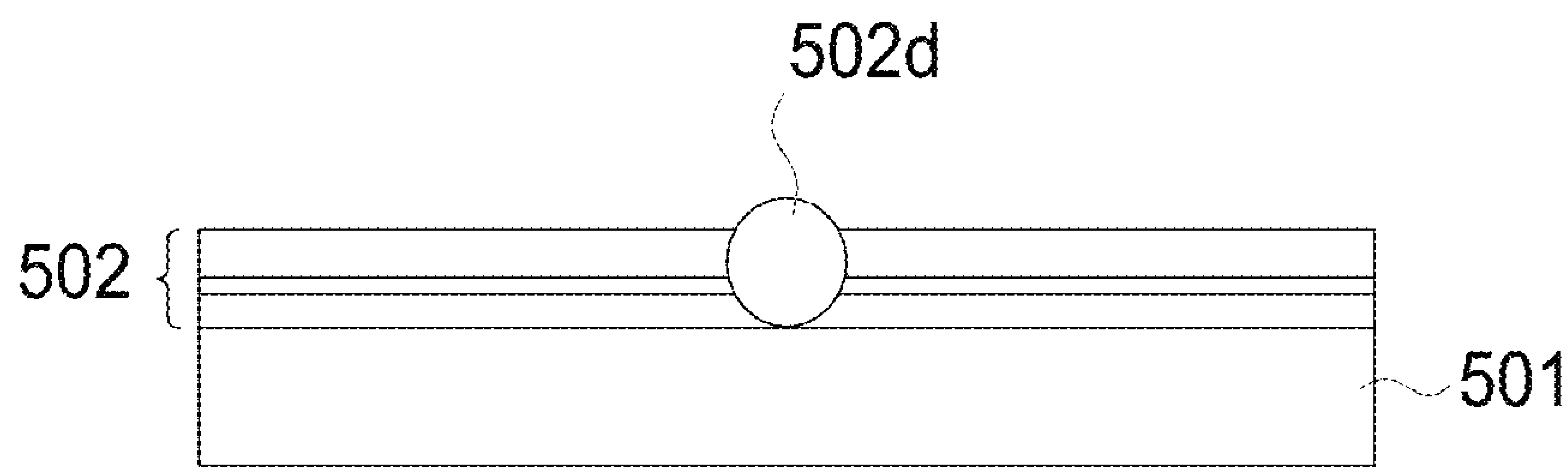


FIG.5A

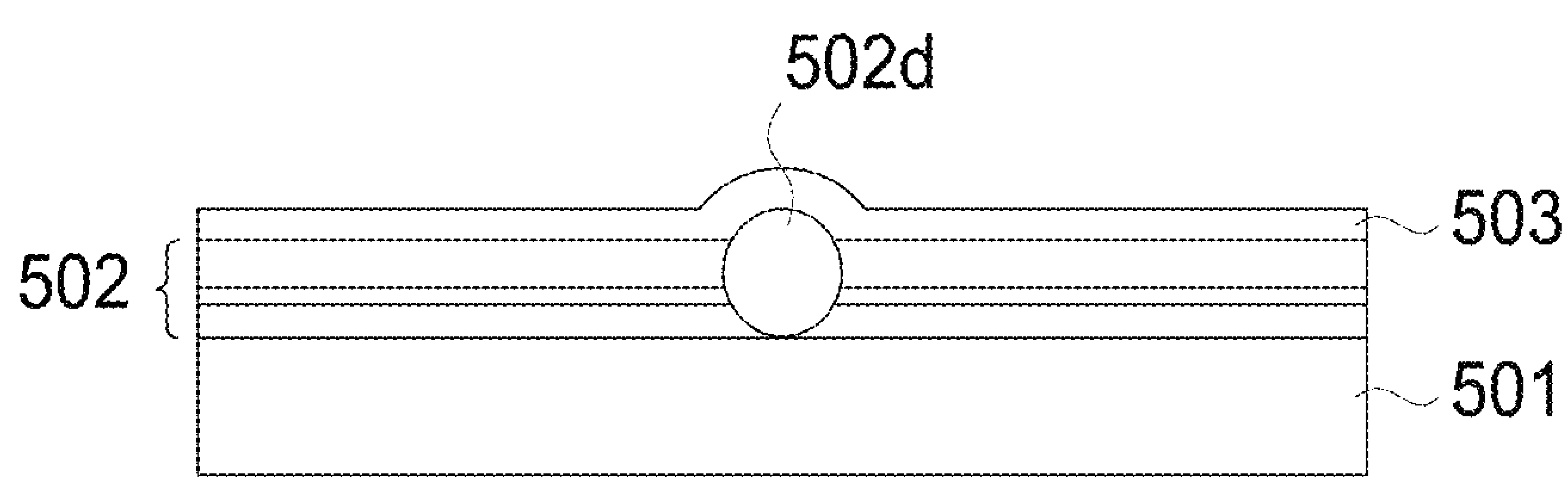


FIG.5B

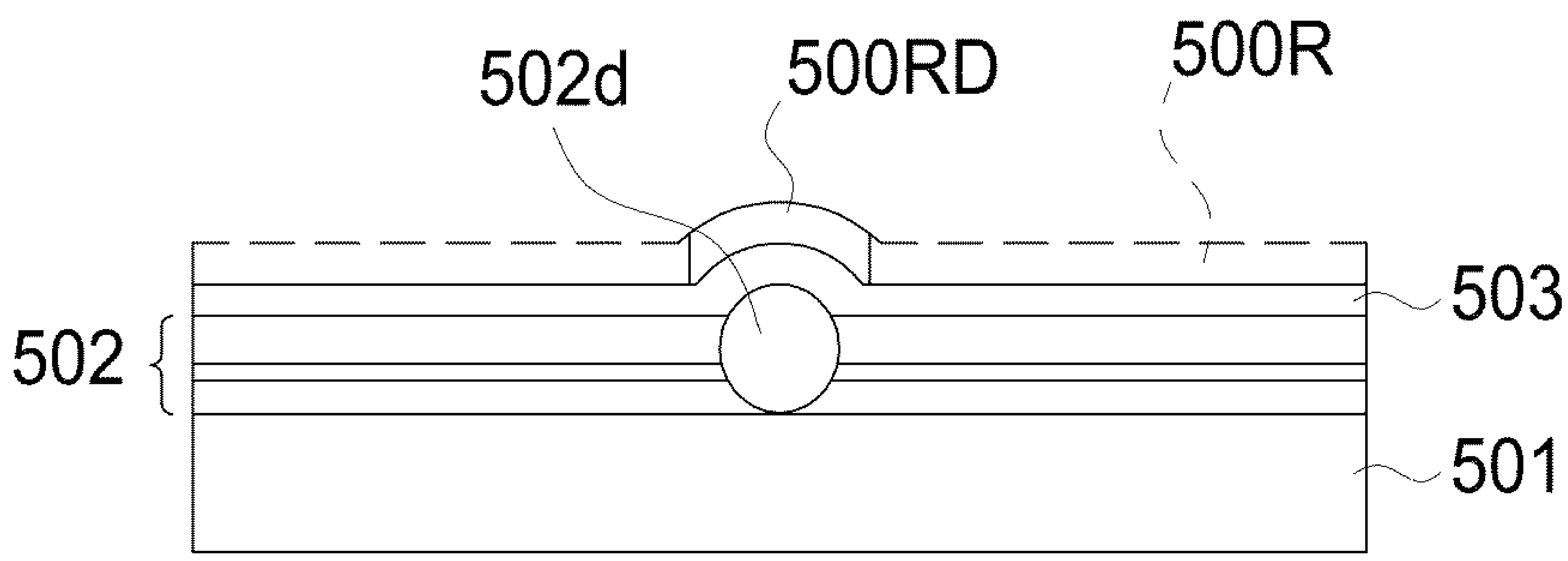


FIG.5C

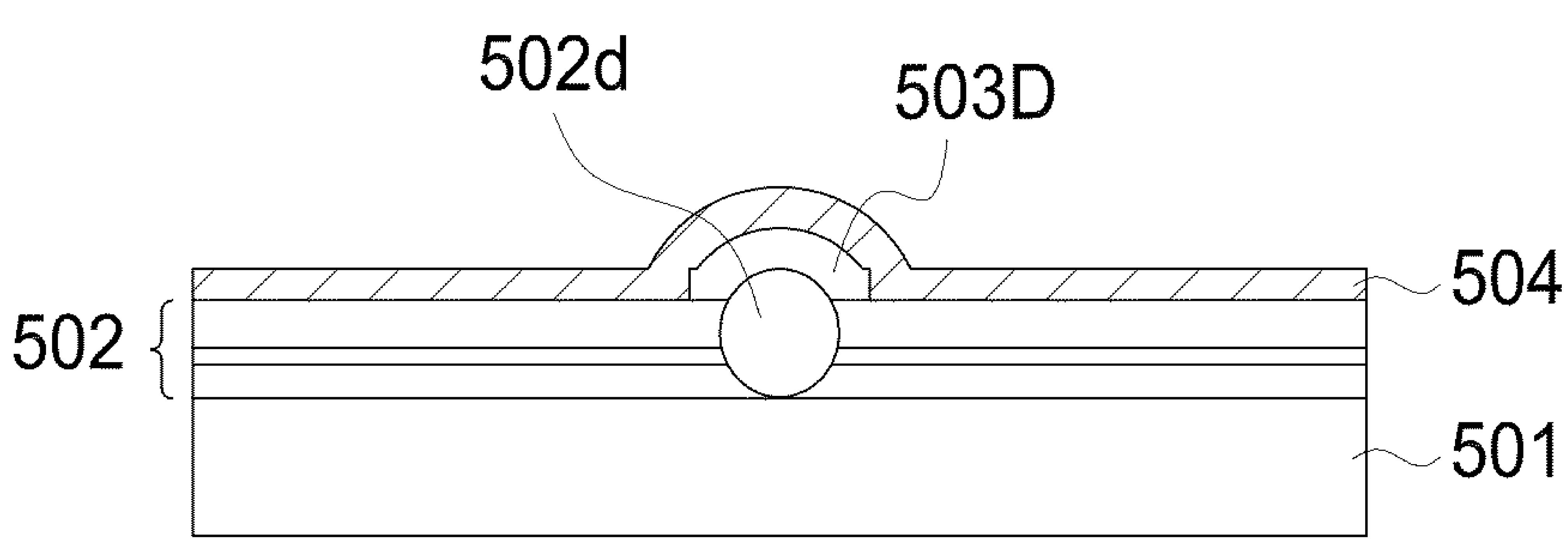


FIG.5D

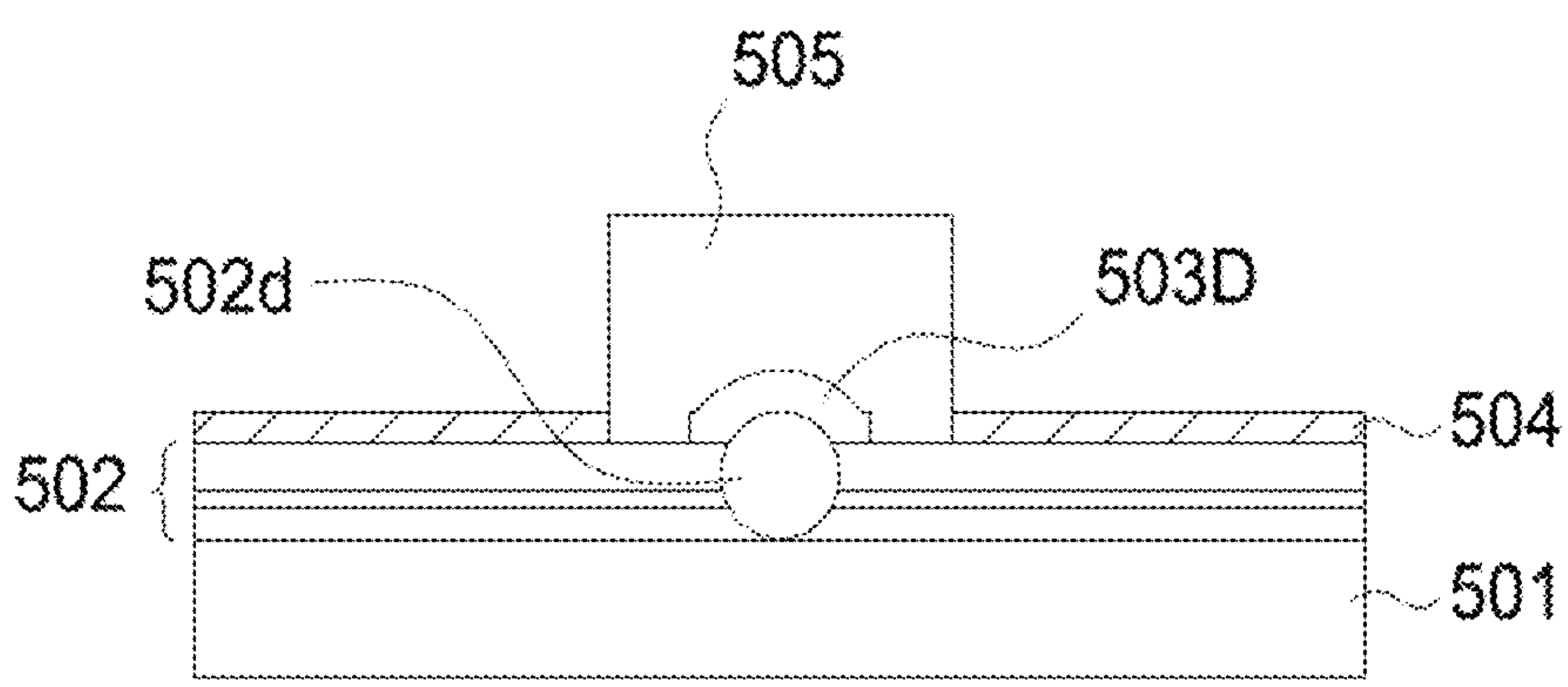


FIG.5E

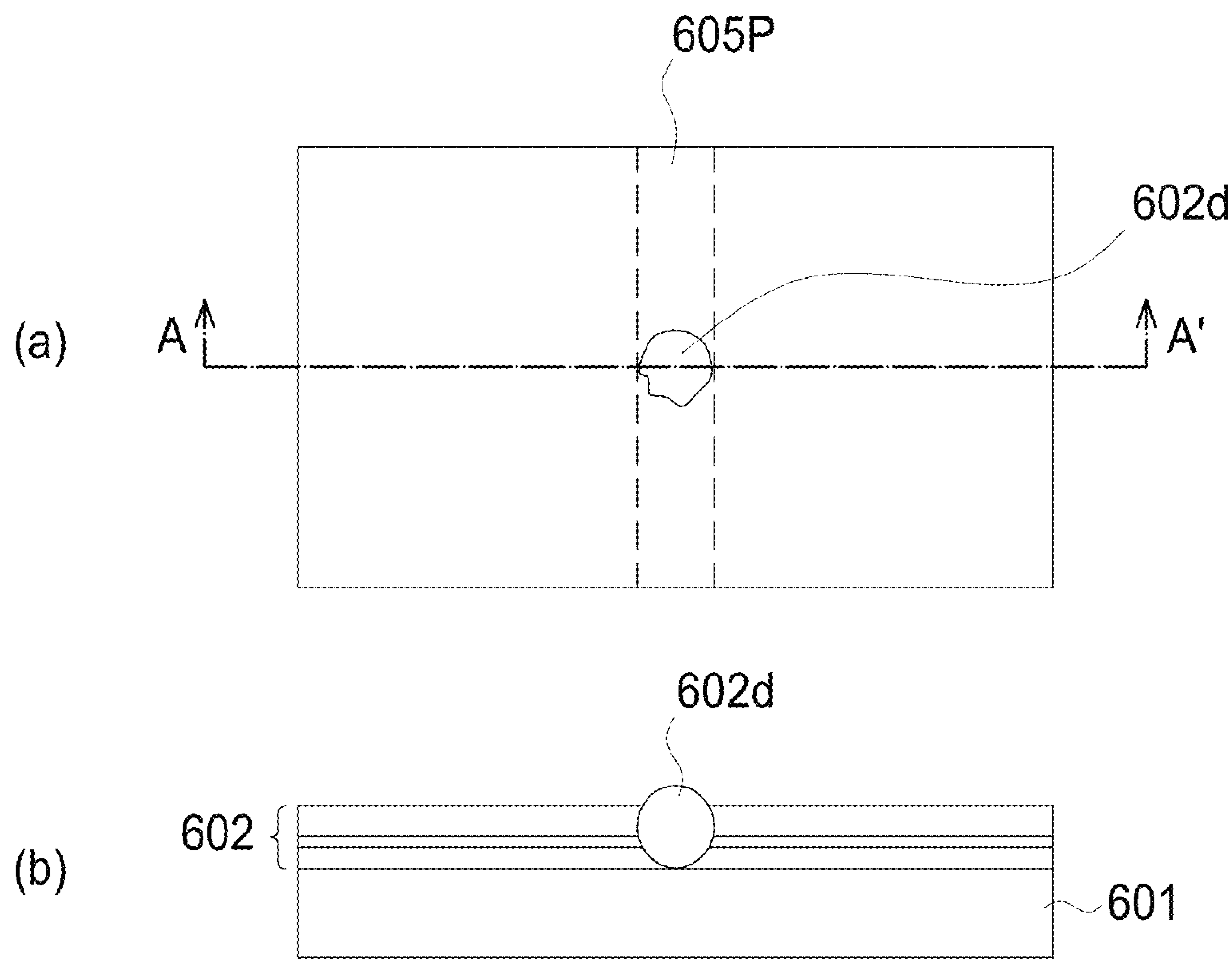


FIG.6A

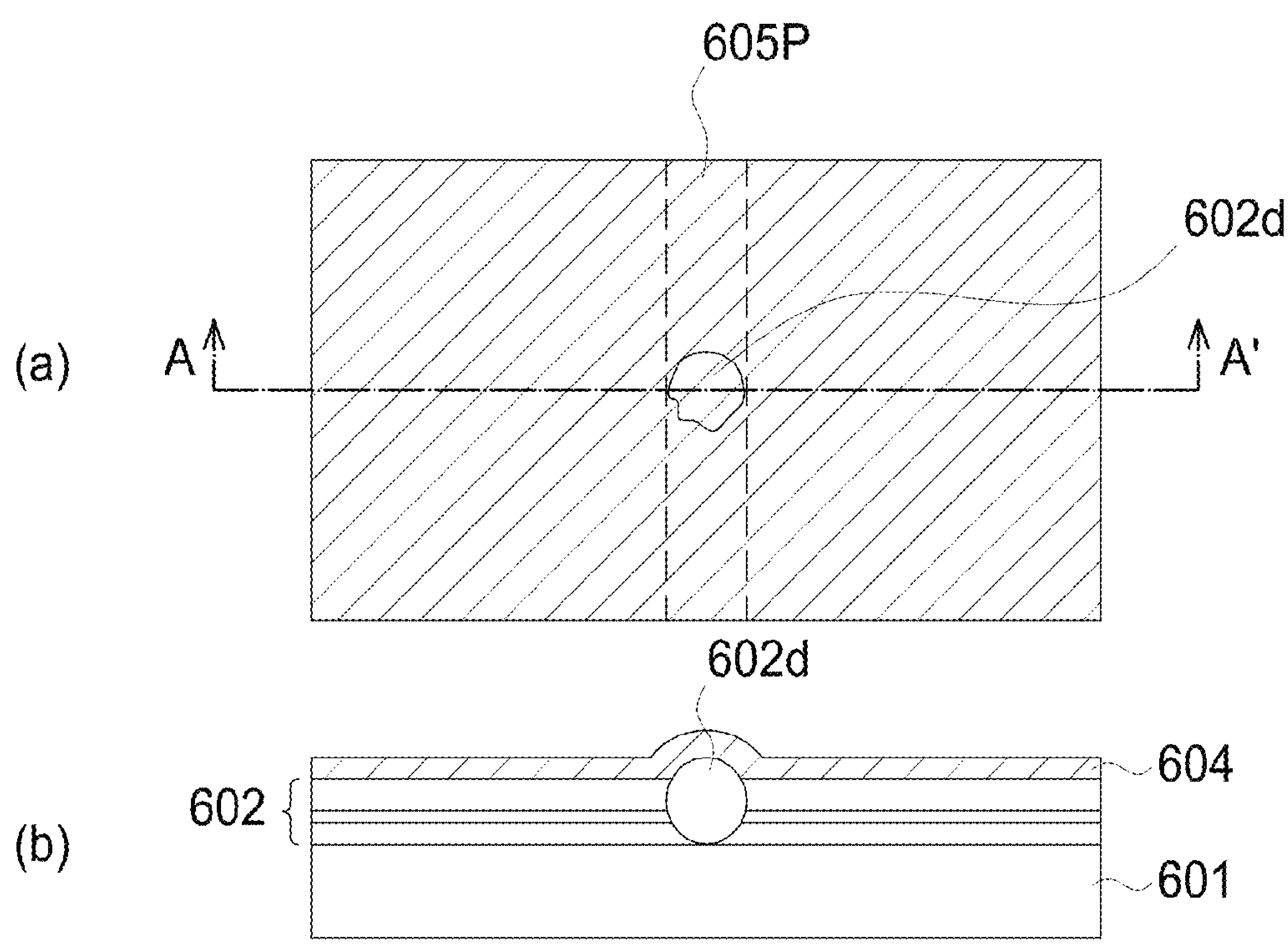


FIG.6B

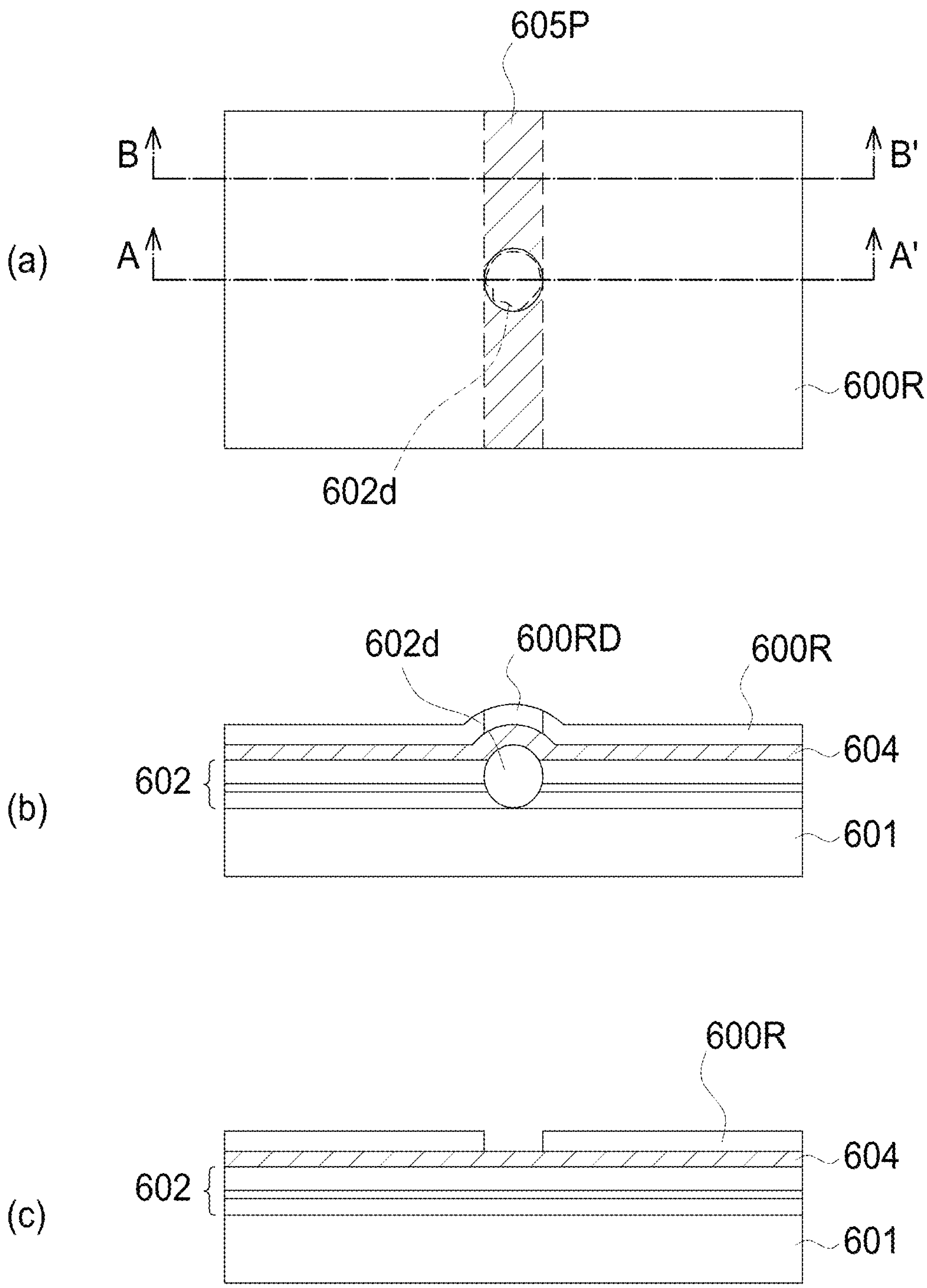

605P
B
B'
A
A'
(a)
600R
602d
602d
600RD
600R
604
602
(b)
601
600R
604
602
(c)
601

FIG.6C

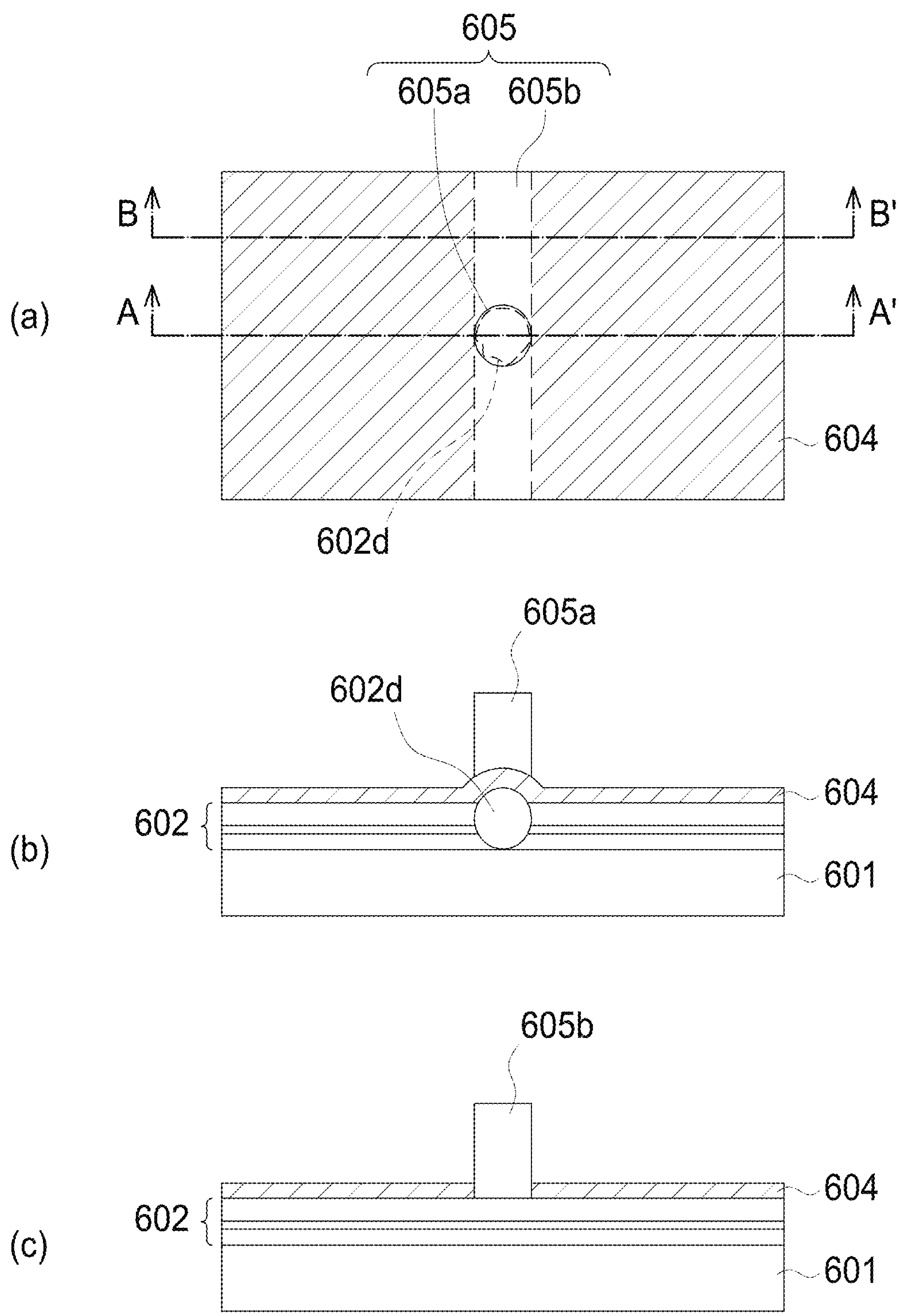

605
605a
605b
B
B'
A
A'
(a)
604
602d
605a
602d
602
(b)
604
601
605b
602
(c)
604
601

FIG.6D

METHOD FOR MAKING SEMICONDUCTOR DEVICE AND SEMICONDUCTOR DEVICE MADE THEREBY

REFERENCE TO RELATED APPLICATION

This application is a continuation-in-part of U.S. patent application Ser. No. 13/741,938, entitled "Method and Apparatus for Making a Semiconductor Device", filed on Jan. 15, 2013, now pending, the entire content of which is incorporated herein by reference.

TECHNICAL FIELD

The application relates to a method for making a semiconductor device, and more particular to a method for yield enhancement of making a semiconductor device by detecting a defect included in an epitaxial layer of the semiconductor device and forming a photo-resistor comprising a region substantially corresponding to the detected defect. The semiconductor device made by the method is also disclosed.

DESCRIPTION OF BACKGROUND ART

Because the petroleum source is limited, various kinds of substitutive energy are developed extensively and turned into products. Among those, the solar cell has become the commercial products for either the industrial or the residential use, and the III-V group material solar cell is mainly applied to the space industry and the industrial field because of its high conversion efficiency.

However, there are many kinds of defects existing in/on the epitaxial layer of III-V group material. For example, as shown in FIG. **1**, a pinhole defect **101** which is usually caused by a dislocation under stress occurs during the epitaxial growth of the III-V group material, and cracks **102** along the lattices also happen, especially in the wafer bonding process or the substrate transferring process. There are other kinds of defects, such as particles on the epitaxial layer or hilllocks which are particles covered by the epitaxial layer and exists in the epitaxial layer. These defects in/on the epitaxial layer result in device problems such as current leakage, and make the photovoltaic device operate abnormally. As the demand for a larger size photovoltaic device increases, the yield loss due to the defect becomes higher. For example, a 4-inch wafer produces only two photovoltaic devices used in aerospace industry, and the defect in/on the epitaxial layer results in 50% yield loss accordingly. In some prior art, a laser is used to burn and remove, the defects. However, it is difficult to remove the residual material produced in the laser treatment, and the residual material may also lead to a current leakage.

SUMMARY OF THE DISCLOSURE

Disclosed is a method for yield enhancement of making a semiconductor device. The method for yield enhancement of making a semiconductor device comprises the steps of: providing the semiconductor device comprising an epitaxial layer including a defect; forming a dielectric layer on the epitaxial layer; detecting and identifying a location of the defect; and etching the dielectric layer and leaving a part of the dielectric layer to cover an area substantially corresponding to the detected defect. The semiconductor device made by the method is also disclosed.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. **1** illustrates defects existing in/on the epitaxial layer of III-V group material of a photovoltaic device known in the prior art.

FIG. **2**A illustrates the function block diagram of the apparatus in accordance with one embodiment of the present application.

FIG. **2**B illustrates the details of a part of the apparatus in FIG. **2**A.

FIGS. **3**A to **3**L illustrate a method in accordance with one embodiment of the present application.

FIG. **4** illustrates the process of the exposing step related to the method in FIGS. **3**A to **3**L.

FIGS. **5**A to **5**E illustrate a method in accordance with the second embodiment of the present application.

FIGS. **6**A to **6**D illustrate a method in accordance with the third embodiment of the present application.

DETAILED DESCRIPTION OF PREFERRED EMBODIMENTS

FIG. **2**A and FIG. **2**B illustrate an apparatus in accordance with one embodiment of the present application. FIG. **2**A shows the function block diagram of the apparatus, and FIG. **2**B illustrates the details of a part of the apparatus. Please refer to FIG. **2**A. The apparatus **200** is used for detecting a defect included in an epitaxial layer on a substrate of a wafer and forming a photo-resistor comprising a region substantially corresponding to the detected defect. The apparatus **200** comprises a coating module **210**, an exposing module **220**, a developing module **230**, and an image recognition system **240**. The apparatus **200** may further comprise a mask-used exposing module **250** to transfer a pattern on a mask, such as cutting lines, to the photo-resistor for use in other process. It is noted that the mask-used exposing "module" can also be in the form of an "apparatus" which is associated with the apparatus **200**. Here a "module" means a part of an "apparatus" and provides a specific function in the apparatus when assembled to the apparatus. A module cannot function independently. In contrast, an apparatus can function independently and can be optionally associated with another apparatus to perform its function. And "associated with" means the electrical signals are exchanged, and sometimes may also mean mechanical connection if necessary.

The coating module **210** is used to coat a photo-resistor on the epitaxial layer. The exposing module **220** comprising a first light source (not shown) is used to expose a part of the photo-resistor. The image recognition system **240** is used to detect the defect and comprises a second light source **241**, an image sensor **242**, and a comparison unit **243**. It is noted that the image recognition system **240** can be set inside the exposing module **220** or a different module separated from the exposing module **220**. In another embodiment, only some elements of the image recognition system **240** such as the second light source **241** and the image sensor **242** are inside the exposing module **220**, and the electrical signals can be exchanged between the image recognition system **240** and the exposing module **220**. In the case that the whole image recognition system **240** is set inside the exposing module **220** or in the case that some elements of the image recognition system **240** are set inside the exposing module **220**, the defect detecting and the exposing step can be performed substantially at the same time. That is, the defect is detected by the image recognition system **240** and the part of the photo-resistor substantially corresponding to the defect detected is exposed by the exposing module **220** immediately. When the image recognition system **240** is not in a module separated from the exposing module **220**, the time interval between the finish of defect detecting and the actuation of the exposing step is very short because there is not time spent on wafer transferring between two separated modules. If the image recognition system **240** is set inside a module separated from the exposing module **220**, the wafer may be first loaded into the module where the image recognition system **240** is set inside to detect the defect, and then the information of the location of the defect detected is sent to the exposing module **220** to which the wafer is then transferred, and the part of the photo-resistor substantially corresponding to the defect detected is exposed accordingly.

As mentioned above, the apparatus **200** may further comprise a mask-used exposing module **250** or be associated with a mask-used exposing apparatus **250** to transfer a pattern on a mask to the photo-resistor. A part of the photo-resistor corresponding to the pattern in the mask may be optionally exposed by the mask-used exposing module (or apparatus) **250** before the detecting step or after the exposing step. The part of the photo-resistor corresponding to the pattern in the mask together with the exposed part of the photo-resistor substantially corresponding to the defect detected may be removed later in a developing step. The developing module **230** is used to develop the exposed photo-resistor so the part of the photo-resistor exposed by the first light source in the exposing module **220** and the part exposed by the mask-used exposing module (or apparatus) **250** are removed after the developing.

Please refer to FIG. **2**B. The left part of the figure illustrates the details of the image recognition system **240** and some parts of the exposing module **220**. The right part of the figure illustrates the mask-used exposing module (or apparatus) **250**. The image recognition system **240** comprises elements enclosed by the broken line, i.e. the second light source **241**, the image sensor **242**, and the comparison unit **243**, and the exposing module **220** comprises a first light source **221** and a platform **222**. As mentioned above, the figure shows the case which the whole image recognition system **240** is set inside the exposing module **220** and the electrical signals of the image recognition system **240** and the exposing module **220** are exchanged so that the detecting of the defect and the exposing step are performed substantially at the same time. A wafer **201** is loaded into the exposing module **220** and disposed on a platform **222** of the exposing module **220**. The platform **222** carries the wafer **201** and moves under the first light source **221** of the exposing module **220** and the second light source **241** and the image sensor **242** of the image recognition system **240**. The second light source **241** provides illumination for image recognition and is different from the first light source **221** used for exposing. For example, when the photo-resistor is a positive type photo-resistor, the first light source is UV light which causes the positive type photo-resistor to have a chemical reaction, and the second light source is non-UV light which provides illumination for image recognition and does not cause the positive type photo-resistor to have a chemical reaction. The image sensor **242** is used to capture an image of a pattern on the epitaxial layer on the wafer **201**. The image sensor **242** comprises, for example, a CCD (Charge-coupled Device) or a CMOS image sensor. The comparison unit **243** is used to compare the image of the pattern captured by the image sensor **242** with a pre-determined pattern stored in the comparison unit **243** for determining whether the pattern is a defect or not. The whole image recognition system **240** is set inside the exposing module **220** and the electrical signals of the image recognition system **240** and associated with the exposing module **220** are exchanged so that the detecting of the defect and the exposing step are performed substantially at the same time. That is, the wafer **201** is moved to be scanned by the image sensor **242**, and when a defect is determined by the comparison unit **243**, a signal from the comparison unit **243** is transferred to the exposing module **220** so that the first light source **221** is actuated to expose the part of the photo-resistor substantially corresponding to the defect detected.

In addition, as mentioned in FIG. **2**A, the wafer **201** may be optionally transferred to the mask-used exposing module (or apparatus) **250** before the detecting step or after the exposing step. It is noted that when the wafer **201** is transferred to the mask-used exposing module (or apparatus) **250** before the detecting step, the wafer **201** is transferred directly from the coating module **210** after the aforementioned coating step.

The mask-used exposing module (or apparatus) **250** comprises a mask table **253** on which a mask **202** is disposed, a platform **252** on which the wafer **201** is disposed on, and a light source **251**. A part of the photo-resistor corresponding to a pattern in the mask **202** may be optionally exposed by the mask-used exposing module (or apparatus) **250** with the light source **251** before the detecting step or after the exposing step. The light source **251** may be the same as the first light source **221**, UV light. The pattern in the mask **202** comprises, for example, cutting lines around a solar cell chip.

FIGS. **3**A to **3**L illustrate a method in accordance with one embodiment of the present application. The method is used for removing a defect from an epitaxial layer on a substrate of a wafer and can be further used for forming a photovoltaic device. The method may be carried out with the utilization of the apparatus as previously illustrated in FIGS. **2**A and **2**B.

As shown in FIG. **3**A, the method comprises providing a wafer comprising a substrate **301** on which an epitaxial stack **302** is formed first. The epitaxial stack **302** comprises a plurality of layers of III-V group material to form at least one p-n junction of a solar cell. The epitaxial stack **302** comprises a defect **302***d*. The defect **302***d* may be any one of those illustrated in FIG. **1**. In FIG. **3**B, a photo-resistor **300***r* is coated on the epitaxial stack **302** by the aforementioned coating module **210**. The wafer is then transferred to the aforementioned mask-used exposing module (or apparatus) **250** directly from the coating module **210** after the coating step. As mentioned above, this embodiment illustrates a case which a mask-used exposing is performed before a defect detecting step. The defect detecting step will be illustrated later in FIG. **3**C. In the embodiment, a mask **300**M is used, and the pattern in the mask **300**M, which is a pattern for cutting lines **300**MC around a solar cell chip, is transferred to the photo-resistor **300***r* with an exposing by light (as the arrows shows) from the light source **251** of the mask-used exposing module (or apparatus) **250** shown in FIG. **2**B. The exposed pattern **300***rc* in the photo-resistor **300***r* is used for forming the cutting lines in the wafer as will be illustrated later in FIG. **3**E.

As shown in FIG. **3**C, this embodiment illustrates a case which the detecting of the defect and an exposing step are performed substantially at the same time by using the apparatus shown in FIG. **2**B, and the wafer is transferred to the aforementioned exposing module **220** and a defect detecting step is performed. The wafer is scanned by the aforementioned image sensor **242** with the illumination provided by light from the second light source **241**. And once a defect, for example, the defect **302***d* is detected, the first light source **221** is actuated to expose the part of the photo-resistor **300***rd* which is substantially corresponding to the defect detected. The first light source **221** used for exposing is different from the second light source **241** for image recognition. For example, the photo-resistor **300***r* in this embodiment is a positive type photo-resistor, and the first light source **221** is UV light which causes the positive type photo-resistor **300***r* to have a chemical reaction, and the second light source **241** is non-UV light which provides illumination for image recognition and does not cause the positive type photo-resistor to have a chemical reaction. The process of the exposing step is illustrated in FIG. **4**. In FIG. **4**, the light from the first light source **221** is projected onto the defect and forms a spot as denoted as a circle. The wafer is moved as the aforementioned platform **222** carrying the wafer moves, and spots are formed upon the wafer. In this example, as mentioned previously in FIG. **1**, two kinds of defects, i.e., a pinhole defect **101** and cracks **102** are shown, and the area of these defects forms a defect area. The spots as denoted are formed substantially along the contour of the defect area and cover the whole defect area. Finally, the collection of these circles forms the exposed part as denoted by the solid line in the figure to cover the defect area. The area of the exposed part is substantial the same as or a little larger than the defect area. It is noted that the information of the location of the defect detected may be stored in the same apparatus or sent to another apparatus for a later use.

And then as shown in FIG. **3**D, the wafer is transferred to the aforementioned developing module **230**, and the photo-resistor **300***r* is developed to remove the exposed part of the photo-resistor **300***r* so that a subsequent etch process is performed with the developed photo-resistor **300***r* as a mask to remove the part of the epitaxial layer where the photo-resistor is removed. The result after the etch process is shown in FIG. **3**E where an empty part **302***d*' substantially corresponding to the defect **302***d* detected and an empty part **302***c* corresponding to a cutting line are formed in the epitaxial stack. The etch process may be a dry etch or a wet etch, and the photo-resistor **300***r* is removed after the etch process. Then as shown in FIGS. **3**F to **3**J, a dielectric material is formed substantially in the region where the epitaxial stack **302** is removed; in other words, a dielectric material is formed in the empty part **302***d*' and the empty part **302***c* shown in FIG. **3**E. As shown in FIG. **3**F, a dielectric layer **303** is formed. The dielectric layer **303** may be, for example, alumina, titanium dioxide, silicon nitride (Silsk) or silicon oxide (SiO_x). In FIG. **30**, a negative photo-resistor **300**R is coated on the dielectric layer **303**, and an exposing is performed on the photo-resistor **300**R with a mask **300**M2. The area of the pattern **300**M2C may be a little larger than the area of the pattern **300**MC in FIG. **3**B. The exposing can be performed by the mask-used exposing module (or apparatus) **250**. Since the photo-resistor **300**R is a negative type, as will be illustrated in FIG. **3**I, the exposed part is left as a remaining part after developing. And then in FIG. **3**H, the information of the location of the defect detected stored as previously mentioned in FIG. **3**C is used so that an exposing step may be carried out accordingly. The area of the exposed part can be substantial the same as or a little larger than the area of the empty part **302***d*' shown in FIG. **3**E. As a result, as shown in FIG. **3**I, after a developing step, a first remaining part **300**RD substantially corresponding to the area of the defect **302***d* detected and a second remaining part **300**RC corresponding to cutting lines of the negative photo-resistor **300**R are formed on the dielectric layer **303**. And then in FIG. **3**J, an etch process is performed to remove the part of the dielectric layer **303** uncovered by the first remaining part **300**RD and the second remaining part **300**RC of the photo-resistor **300**R, and dielectric material **303**D and **303**C is formed substantially in the region where the epitaxial layer is removed. The etch process may be a dry etch or a wet etch, and first and second remaining parts **300**RD and **300**RC of the photo-resistor are removed after the etch process. The dielectric material **303**D is formed in the region corresponding to the empty part **302***d*' in FIG. **3**E which is removed for the defect **302***d*, and the dielectric material **303**C is formed in the region corresponding to empty part **302***c* in FIG. **3**E which is removed for the cutting lines **303***c*. The dielectric material **303**D provides an electrical isolation to the sidewalls of the empty part **302***d*', and therefore avoids forming a current leakage path or the failure of the p-n junction in the epitaxial stack **302**. In addition, when an electrode passes or is located on the empty part **302***d*', the dielectric material **303**D provides an electrical isolation between the electrode and the junction to avoids a shortage.

As shown in FIG. **3**K, an anti-reflective layer **304**, the first electrode **305**, and the second electrode **306** are subsequently formed. The main portion of the anti-reflective layer **304** is formed on the epitaxial stack **302** while a portion of the anti-reflective layer **304** is formed on the dielectric material **303**D to fill the concave part caused by the empty part **302***d*' in FIG. **3**E with the dielectric material **303**D formed thereon. The first electrode **305** is formed in the anti-reflective layer **304** and on the epitaxial stack **302**. The second electrode **306** is formed on the surface of substrate **301** opposite to the surface on which the epitaxial stack **302** is disposed. And in FIG. **3**L, as mentioned above, the cutting lines are formed around a solar ell chip, and the substrate **301** is cut along the cutting lines as indicated by the line LL' to form the solar cell chips. It is noted that the process flow shown in this embodiment may be adjusted by the person of the skill in the art. For example, though the cutting line pattern, i.e. the mask-used exposing, is performed before the detecting step in this embodiment, it is apparent that the mask-used exposing may be performed after the detecting step. Besides, the coating step may be performed after the detecting step. For example, the wafer may be first loaded to an separated module where the image recognition system **240** is set inside (or the exposing module **220** comprising an image recognition system set inside it) to have the detecting step performed, and then the wafer is transferred to the coating module **210** to have the coating step performed. And finally the stored information of the location of the detected defect is used in the exposing module **220** to have the exposing step performed accordingly after the coating step. Similarly, the order for the wafer to be transferred between different modules in the apparatus may be designed by the person of the skill in the art accordingly as the above illustration. In addition, though the four modules are integrated in one apparatus as shown in FIG. **2**A, one or more modules may be separated and formed as an independent apparatus by the person of the skill in the art. It is also noted that application of the apparatus and the method illustrated in the present application is not limited to a photovoltaic device, and can be commonly used for a semiconductor device, such as an LED. The yield of the semiconductor device is enhanced by detecting and removing the defect included in an epitaxial layer of the semiconductor device and forming a dielectric material in the region where the epitaxial layer is removed to provide an electrical isolation and avoid problems such as current leakage.

FIGS. **5**A to **5**E illustrate the method in accordance with the second embodiment of the present application, which is also a method for yield enhancement of making a semiconductor device by detecting a defect. The defect may be any one of those illustrated in FIG. **1**. Compared with the method illustrated in FIGS. **3**A to **3**L which removes the defect, a dielectric layer is used to cover the detected defect instead of removing the defect in the present embodiment. Like the embodiment illustrated in FIGS. **3**A to **3**L, the method can also be used for forming a photovoltaic device and be carried out with the utilization of the apparatus as previously illustrated in FIGS. **2**A and **2**B.

As shown in FIG. **5**A, the method comprises the steps of providing a wafer comprising a substrate **501** on which an epitaxial stack **502** is formed. A defect **502***d* is included in the epitaxial stack **502**. The epitaxial stack **502** comprises a plurality of layers of III-V group material to form at least one p-n junction of a solar cell. In FIG. **5**B, a dielectric layer **503** is formed on the epitaxial stack **502**. For example, the dielectric layer **503** may comprise silicon oxide or silicon nitride. And then, as shown in FIG. **5**C, the defect **502***d* is detected and the location of the defect **502***d* is identified so that a photo-resistor **500**RD (a part of the photo-resistor **500**R) is formed on the dielectric layer **503**. As mentioned above, the apparatus as previously illustrated in FIGS. **2**A and **2**B (or more specifically, the image recognition system **240**) may be used to detect and identify the location of the defect **502***d*. Similarly, the coating module **210** may be used to coat the photo-resistor **500**R on the dielectric layer **503**, and the exposing module **220** may be used to expose a part of the photo-resistor **500**R. And as previous illustrated, the exposure can be performed according to an information of the location of the defect **502***d* provided by the image recognition system **240**. After development by the developing module **230**, the photo-resistor **500**RD, which is a part of the photo-resistor **500**R, is left on the dielectric layer **503** in an area substantially corresponding to the defect **502***d*. The processes may be similar to those illustrated in FIG. **3**I. That is, the photo-resistor **500**R may be a negative type, and the photo-resistor **500**RD is exposed and left as a remaining part after developing. The area of the photo-resistor **500**RD can be substantial the same as or a little larger than the area of the defect **502***d*. In addition, when the photo-resistor **500**RD is exposed, it may be exposed by a first light source different from a second light source used in the image recognition system **240** for detecting and identifying the location of the defect. In an alternative embodiment, the photo-resistor **500**RD may be formed on the dielectric layer **503** manually. It can be that an operator manually dispenses the photo-resistor **500**RD on the dielectric layer **503** only in the area substantially corresponding to the defect **502***d* according to an information of the location of the defect **502***d* provided by the image recognition system **240** after the detection.

As shown in FIG. **5**D, after the photo-resistor **500**RD is formed on the dielectric layer **503**, an etch process is performed to remove the part of the dielectric layer **503** which is uncovered by the photo-resistor **500**RD. A part of the dielectric layer **503**, i.e. **503**D, is left to cover the area substantially corresponding to the detected defect **502***d*. The photo-resistor **500**RD is removed after the etch process. The dielectric material **503**D provides an electrical isolation to the layers subsequently formed thereon, especially to an electrode, and therefore avoids forming a current leakage path or the failure due to shortage caused by the defect **502***d*. Accordingly, the yield is enhanced. As shown in the figure, an anti-reflective layer **504** is subsequently formed.

As shown in FIG. **5**E, a first electrode **505** is subsequently formed in the anti-reflective layer **504** and on the epitaxial stack **502**. The present embodiment illustrates that the first electrode **505** passes over the defect **502***d*. Because part of the dielectric layer **503**D covers the area substantially corresponding to the defect **502***d*, the first electrode **505** does not contact the defect **502***d* directly. That is, the dielectric layer **503**D is disposed between the first electrode **505** and the defect **502***d*, and forms an electrical isolation to the first electrode **505**. Therefore, though the defect **502***d* is not removed as the method illustrated in FIGS. **3**A to **3**L, the yield is still improved.

FIGS. **6**A to **6**D illustrate a method in accordance with the third embodiment of the present application. This embodiment is a modification of the embodiment shown in FIGS. **5**A to **5**E. Compared with the method illustrated in FIGS. **5**A to **5**E which has the dielectric layer **503**D, an anti-reflective layer is used instead of the dielectric layer **503**D to cover the defect and provide an electrical isolation in the present embodiment. Like the embodiment illustrated in FIGS. **5**A to **5**E, the method can also be used for forming a photovoltaic device and be carried out with the utilization of the apparatus as previously illustrated in FIGS. **2**A and **2**B. And for some elements which are the same as the elements in FIGS. **5**A to **5**E, the first digit of the label code for such element is changed from "5" to "6" in FIGS. **6**A to **6**D. For example, the element **602** which corresponds to the epitaxial stack **502** in FIGS. **5**A to **5**E is also an epitaxial stack **602** in FIGS. **6**A to **6**D.

It is noted that in FIGS. **6**A to **6**D, the figures labeled with "(a)" show the top views of the photovoltaic device to be illustrated, the figures labeled with "(b)" show the cross-sectional views along the line A-A' in the top views, and the figures labeled with "(c)" (in FIGS. **6**C and **6**D) show the cross-sectional views along the line B-B'. As shown in FIG. **6**A, the method comprises the steps of providing a wafer comprising a substrate **601** (see figure (b)) on which an epitaxial stack **602** is formed. A defect **602***d* is included in the epitaxial stack **602**. The epitaxial stack **602** comprises a plurality of layers of III-V group material to form at least one p-n junction of a solar cell. It is noted that the present embodiment also illustrates that a first electrode **605** (to be illustrated later in FIG. **6**D) passes over the defect **602***d*. The area **605**P between the two dash lines is the position where the first electrode **605** is disposed. In FIG. **6**B, an anti-reflective layer **604** is formed on the epitaxial stack **602** (see figure (b)). For example, the anti-reflective layer **604** may comprise aluminum oxide (Al_2O_3) or titanium dioxide (TiO_2). As mentioned above, the anti-refletive layer **604** is used instead of the dielectric layer **503**D in the previous embodiment to cover the defect **602***d* and provide an electrical isolation. And then, as shown in FIG. **6**C, the defect **602***d* is detected and the location of the defect **602***d* is identified, so that a photo-resistor **600**RD (see figure (b), the photo-resistor **600**RD is a part of the photo-resistor **600**R) is formed on the anti-reflective layer **604**. As mentioned above, the apparatus as previously illustrated in FIGS. **2**A and **2**B (or more specifically, the image recognition system **240**) may be used to detect and identify the location of the defect **602***d*. Similarly, the coating module **210** may be used to coat the photo-resistor **600**R on the anti-reflective layer **604**, and the exposing module **220** may be used to expose a part of the photo-resistor **600**R. And as previous illustrated, the exposure can be performed according to an information of the location of the defect **602***d* provided by the image recognition system **240**. After development by the developing module **230**, the photo-resistor **600**RD, which is a part of the photo-resistor **600**R, is left on the anti-reflective layer **604** in an area substantially corresponding to the defect **602***d* (see figure (a), the photo-resistor **600**RD is denoted by the circle which covers the defect **602***d*). The processes may be similar to those illustrated in FIG. **3**I. That is, the photo-resistor **600**R may be a negative type, and the photo-resistor **600**RD is exposed and left as a remaining part after developing. The area of the photo-resistor **600**RD can be substantial the same as or a little larger than the area of the defect **602***d*. In addition, when the photo-resistor **600**RD is exposed, it may be exposed by a first light source different from a second light source used in the image recognition system **240** for detecting and identifying the location of the defect. As mentioned above, because the present embodiment illustrates that the first electrode **605** (to be illustrated later in FIG. **6**D) passes over the defect **502***d*, a mask is provided to the apparatus illustrated in FIGS. **2**A and **2**B to expose the pattern for an electrode, i.e. the area **605**P. The photo-resistor

600R in the area **605**P (between the two dash lines) where the first electrode **605** is disposed is removed (except that the photo-resistor **600**RD denoted by the circle is left) after development. The cross-sectional view along the line B-B' shown in figure (c) indicates that the photo-resistor **600**R in the area **605**P (between the two dash lines) is removed to expose the anti-reflective layer **604**. In an alternative embodiment, the photo-resistor **600**RD (denoted by the circle in figure (a)) may be formed on the anti-reflective layer **604** manually. For example, after the electrode pattern (i.e. the area **605**P) is developed as described above, an operator can manually dispense the photo-resistor **600**RD on the anti-reflective layer **604** in the area substantially corresponding to the defect **602***d* according to an information of the location of the defect **602***d* provided by the image recognition system **240**.

And then, in FIG. **6**D, after the photo-resistor **600**R (including the photo-resistor **600**RD) is formed on the anti-reflective layer **604**, an etch process is performed to remove the part of the anti-reflective layer **604** which is uncovered by the photo-resistor **600**R. A part of the anti-reflective layer **604** (denoted by the circle in figure (a)) is left to cover the area substantially corresponding to the detected defect **602***d*. The photo-resistor **600**R (including the photo-resistor **600**RD) is removed after the etch process. The anti-reflective layer **604** on the defect **602***d* provides an electrical isolation to the layers subsequently formed thereon, especially to the first electrode **605**, and therefore avoids forming a current leakage path or the failure due to shortage caused by the defect **602***d*. Accordingly, the yield is enhanced. As shown in the figure, the first electrode **605** is subsequently formed. The first electrode **605** comprises a first part **605***a* (denoted by the circle in figure (a)) and a second part **605***b*, wherein the first part **605***a* overlaps the area substantially corresponding to the defect **602***d*, and the second part **605***b* does not overlap the area. It is shown in the figure (h) that the first part **605***a* of the electrode **605** is disposed on the anti-reflective layer **604**, and in the figure (c) the second part **605***b* of the electrode **605** is disposed in the anti-reflective layer **604** and on the epitaxial layer **602**. That is, in the figure (b), a part of the anti-reflective layer **604** is disposed between the first electrode **605** and the defect **602***d* to cover the area substantially corresponding to the defect **602***d* so an electrical isolation is formed and the first electrode **605** does not contact the defect **602***d* directly. Therefore, though the defect **602***d* is not removed, the yield is still improved.

According to the above method, a photovoltaic device can be made as shown in FIG. **6**D. The photovoltaic device comprises an epitaxial layer **601'** in which a defect **602***d* is included; a dielectric layer (the anti-reflective layer **604** in the present embodiment) on the epitaxial layer **602** to cover an area substantially corresponding to the defect **602***d*; and an electrode **605** having a first part **605***a* which overlaps the area above the epitaxial layer, the an electrode **605** also having a second part **605***b* which does not overlap the area, and the first part **605***a* of the electrode **605** is on the anti-reflective layer **604**, while the second part **605***b* of the electrode **605** is in the anti-reflective layer **604** and on the epitaxial layer **602**.

The above-mentioned embodiments are only examples to illustrate the principle of the present invention and its effect, rather than be used to limit the present invention. Other alternatives and modifications may be made by a person of ordinary skill in the art of the present application without escaping the spirit and scope of the application, and are within the scope of the present application.

What is claimed is:

1. A method for yield enhancement of making a semiconductor device, comprising the steps of:
- providing the semiconductor device comprising an epitaxial layer including a defect;
- forming a dielectric layer on the epitaxial layer;
- detecting and identifying a location of the defect;
- etching the dielectric layer and leaving a part of the dielectric layer to cover an area substantially corresponding to the detected defect;
- forming a photo-resist on the dielectric layer in the area substantially corresponding to the detected defect before etching the dielectric layer; and
- forming an electrode comprising a first part and a second part, wherein the first part overlaps the area and the second part does not overlap the area,
- wherein detecting and identifying the location of the defect is performed by an image recognition system, and
- wherein the step of forming a photo-resist on the dielectric layer in an area substantially corresponding to the detected defect comprises coating the photo-resist on the dielectric layer and exposing a part of the photo-resist according to an information of the location of the defect provided by the image recognition system.

2. The method as claimed in claim **1**, wherein the dielectric layer comprises an anti-reflective layer.

3. The method as claimed in claim **2**, wherein the first part of the electrode is disposed on the anti-reflective layer, and the second part of the electrode is disposed in the anti-reflective layer and on the epitaxial layer.

4. The method as claimed in claim **1**, wherein the dielectric layer comprises silicon oxide or silicon nitride.

5. The method as claimed in claim **1**, further comprising forming an anti-reflective layer on the dielectric layer.

6. The method as claimed in claim **5**, further comprising forming an electrode comprising a first part and a second part, wherein the first part overlaps the area and the second part does not overlap the area.

7. The method as claimed in claim **6**, wherein the first part of the electrode is disposed on the anti-reflective layer, and the second part of the electrode is disposed in the anti-reflective layer and on the dielectric layer.

8. The method as claimed in claim **5**, wherein the dielectric layer comprises silicon oxide or silicon nitride.

9. The method as claimed in claim **1**, wherein exposing a part of the photo-resist is performed with a first light source different from a second light source used in the image recognition system for detecting and identifying the location of the defect.

10. The method as claimed in claim **1**, wherein the step of forming a photo-resist on the dielectric layer in an area substantially corresponding to the detected defect is performed manually.

11. The method as claimed in claim **1**, further comprising providing a mask and exposing the photo-resist with the mask to expose a pattern for an electrode on the photo-resist.

12. A method for yield enhancement of making a semiconductor device, comprising the steps of:
- providing the semiconductor device comprising an epitaxial layer including a defect;
- forming a dielectric layer on the epitaxial layer, the dielectric layer comprising an anti-reflective layer;
- detecting and identifying a location of the defect;
- etching the dielectric layer and leaving a part of the dielectric layer to cover an area substantially corresponding to the detected defect; and

forming an electrode comprising a first part and a second part, wherein the first part overlaps the area and the second part does not overlap the area, wherein the dielectric layer comprises an anti-reflective layer.

13. The method as claimed in claim **12**, wherein the first part of the electrode is disposed on the anti-reflective layer, and the second part of the electrode is disposed in the anti-reflective layer and on the epitaxial layer.

14. The method as claimed in claim **12**, wherein the dielectric layer comprises silicon oxide or silicon nitride.

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